Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 9 (2011) 169 – 173

Procedia Environmental Sciences

Ecological engineering: from concepts to applications

# Possibility of using diverse plant litter in soil restoration processes

M. Szanser[a,] *, Alina Kusińska[b,c], Marcin Kisiel[b], D. Sieminiak[d]

[a]*Centre for Ecological Research, Polish Academy of Sciences, Konopnickiej str. 1, Łomianki 05-092, Poland*

[b]*Warsaw Agricultural University, Faculty of Agriculture and Biology, Department of Soil Environment Science, 159, Nowoursynowska St., Warsaw 02-776, Poland*

[c]*Institute of Civil Engineering, Warsaw University of Technology, 17, Łukasiewicza St., Płock 09-400, Poland*

[d]*Institute of Agricultural and Forest Environment, Polish Academy of Sciences, Department of Agricultural Systems, 74, Szeherezady St., Poznań 60-195, Poland*

**Elsevier use only:** Received date here; revised date here; accepted date here

**Abstract**

We evaluated the effect of mulching degraded soil with plant litter composed of single or mixed species on humus accumulation and algal biomass in experimental field study. Sandy loam (sand mixed with loam) mesocosms were examined over the course of 2.5 years. Five litters composed of meadow plants; both grasses and herbs were used: single species (I - *Dactylis glomerata*, II - *Festuca rubra* and III - *Trifolium pratense*) and species mixtures IV (mixture of 3 species I, II and III); V (mixture of 12 species - IV and 9 other grasses and herbs). The highest humus acid (sum of fulvic and humic acids) content and algal biomass were found under the most diverse litter (V) when compared to other treatments. In general, the results suggest that mulching with diverse plant litter is the most effective.



Selection and/or peer-review under responsibility of Laboratory "Biochemistry and ecology of continental environments

*Keywords:* algae; biodiversity; humus accumulation; litter; mulching

## 1. Introduction

Compared to native plant communities, drastic reductions of plant species richness are commonly observed in agricultural and deteriorated ecosystems [1,2,3,4]. Intensification of agriculture and land devastation often leads to losses of organic matter, primarily humus [4,5,6]. Humus plays an important role in the ecosystem functioning. It stores nutrients, improves soil structure and biological activity. One of the measures against soil organic matter loss is the mulching the soil surface with plant-derived matter. Mulching is usually done by using the agricultural crop residues (e.g. wheat and rice straw, grass etc.). This technique allows restoration of deteriorated soil systems as it usually improves soil physico-chemical and biological parameters resulting in higher water infiltration rate, organic matter content and microbial activity [6,7,8,9]. But still there is little information concerning the effect of mulching by plant mixtures.

Our previous research on the relationship between carbon sequestration and food web complexity allowed to conclude that increased carbon sequestration proceeded more intensively in ecosystems with more diverse

* Corresponding author. Tel.: +48-22-751-30-46; fax: +48-22-751-31-57.
*E-mail address:* mszanser@gmail.com (M. Szanser).

1878-0296 
Selection and/or peer-review under responsibility of Laboratory "Biochemistry and ecology of continental environments
doi:10.1016/j.proenv.2011.11.025

vegetation and more complex food webs than in those with simplified species composition [10,11]. Enhancing crop diversity resulted in 5% increase of soil C [12]. Similarly, Ponge [13] suggested that diversity plays a central role in the humus formation in terrestrial ecosystems.

The impact of decreasing both taxonomic and functional diversity on soil processes is largely unknown [14,15,16,17]. Changes in telluric algal biomass are particularly neglected in soil studies, comparing to other microbial components, but some data point out the importance of soil algae in soil functioning and humus formation [18,19].

In this paper, we present the results of the effect of experimental mulching with plant litters differentiated by species richness. Our primary objective was to assess the hypothesis that the mulching with litter composed of diverse meadow plant species enhances the accumulation of humus in soil.

## 2. Methods

The study was conducted in a permanent meadow (of the type Arrhenatheretalia) situated in the buffer zone of the Kampinos National Park (52° 22′ 43.6″ N, 20° 47′ 20.2″ E, east-central Poland) [20]. The mean precipitation in the study period was lower than the long-term mean being 440 mm and 517 mm, respectively. Air temperature in the growing seasons was higher than the long-term mean being 14.4°C and 13.6°C, respectively. During sampling times, no differences in moisture were found between particular litter treatments, either in the litter itself or in the substrate [18].

The experimental meadow of an area of 190 x 10 m had 110 microplots (0.5 x 0.5m area and 0.15 m depth). Five litter treatments in 22 plot replicates according to Randomized Complete Box (RCB) design were applied [21]. Eight litter containers per plot were placed. Litter was obtained from meadow plants, both grasses and weeds cut in August 2001 which had to simulate the input of decaying plants to soil. The same amount of litter (9 g dry wt.) irrespective of the number of plant species was exposed in modified litter containers [18]. Experimental plots were filled with light loamy sand (sand mixed with loam) to the depth of 15 cm [18]. The organic carbon content in this substrate at the beginning of the experiment was Corg. - 44.35 mg 100 $g^{-1}$, $C_{HA}$ (humic acid-like carbon) - 7.81 mg 100 $g^{-1}$, and $C_{FA}$ (fulvic acid-like carbon) -14.96 mg 100 $g^{-1}$. Such type of simplified soil had to increase the sorption capacity of substrate and to decrease the outwashing of humic substances [18,22]. Sand in plots was separated from the surrounding soil by a foil which had to prevent from roots growing into experimental substrate.

Litter of the following species composition was applied: I – the cocksfoot – *Dactylis glomerata* (C:N ratio = 20.79), II – the red fescue – *Festuca rubra* (C:N ratio = 38.42), III – the red clover – *Trifolium pratense* (C:N ratio = 18.24), IV – mixture of the three plant species from treatments I, II and III applied in equal proportions (C:N ratio = 20.28), V – mixture of 12 plant species (combined litter of I – III + 9 other species; C:N ratio = 19.97). The last treatments were composed of grasses: the brome grass – *Bromus inermis*, the meadow foxtail – *Alopecurus pratensis*, the perennial ryegrass – *Lolium perenne*, the oat grass – *Arrhenatherum elatius*, the cocksfoot – *Dactylis glomerata*, the red fescue – *Festuca rubra*; and herbs (weedy species): the small plantain – *Plantago lanceolata*, the common chicory – *Cichorium intybus*, the red clover – *Trifolium pratense*, the milfoil – *Achillea millefolium*, the carrot – *Daucus carota*, the common silverweed – *Potentilla anserina*.

Composition of mixtures was selected in a way that the basic differentiating parameter was the number of plant species and not the chemical composition. Some differences in the litter quality could not be avoided, but mixtures had intermediate C:N ratios (*ca.* 20.12).

The experiment started on 24 – 25 March 2002. Samples were taken on 25 June 2002, 27 September 2002, 11 May 2004, and 9 September 2004 i.e. 3, 6, 26 and 30 months since the litter exposure. The number of samples and sampling frequency are presented in Table 1.

The analyses involved an assessment of organic carbon and humus acids fractions content in underlying substrate. The biomass of soil algae was determined.

Litter mass loss was determined using the gravimetric method. Organic carbon was analysed with a Shimadzu TOC 5000A analyser. Humus fractions were separated with sodium pyrophosphate according to Kononova [23]. The methods for measuring soil organic matter are described in Szanser et al [18]. Algal biomass was estimated according to the methods of Wood [24] and Sieminiak [25] with a UV/VIS spectrophotometer model V-550 JASCO. Samples for estimating the chemical and algal parameters were taken from the substratum to the depth of 5 cm with soil corers of area 100 $cm^2$.

Statistical processing of results was performed with the Statistica 8.0 software (StatSoft, Inc. (2007) [26]). One-way ANOVA was applied for testing the effect of treatments on mass of remaining litter, carbon fractions content and algal biomass in soil. All data presented had standard normal distribution.

## 3. Results

The amount of remaining litter was not different in the most diverse treatment (V) comparing to simplified litters (I, II, III, IV) during the course of the experiment (Table 1). The humus and humus acids content in the substrate was not different between treatments after 6 and 26 months of the experiment. Organic carbon content was significantly smaller under the most diverse litter treatment (V) compared to other treatment only after three months of the experiment. It was insignificantly higher under the most diverse treatment (V) compared to others by 9.2% after 30 months of the experiment. On the opposite, the humus acid (sum of humic and fulvic acids) content was significantly higher under the most diverse treatment (V) compared to others after 3 and 30 months of litter exposure (Table 1). At the end of the experiment, it was higher by 16%.

Algae developed mainly in the substrate, while in the litter only trace amounts were found. The algal biomass was very sensitive to the species richness of litter cover. Higher algal biomass was found below the most diverse litter (V) comparing to the rest of treatments. Differences between treatments were highly significant for all data (Table 1). Finally, algal biomass in the most diverse system (V) was higher than in simplified treatments by 59.4%.

Table 1. Differences between 12 species mixture and simplified 1-3 species litter treatments in litter decomposition and in underlying substrate. On each sampling occasion, 6-9 samples of litter per treatment were taken for assessing the litter mass loss. Analogously, 6 samples, pooled to 3, of soil were taken for chemical analyses and algal biomass assessment. Differences between treatments were assessed using the one-way ANOVA. Denotations of treatments: 1-3 species (I – *Dactylis glomerata*, II – *Festuca rubra*, III – *Trifolium pratense*, IV – mixture of plants in treatments I, II & III) and 12 species (V – mixture of 12 meadow plants species plants as in treatment IV + 9 other species)

| Months since litter exposure | Remaining litter | | Corg. content | | Sum of humic acid content $C_{(FA + HA)}$ | | Biomass of algae | |
|---|---|---|---|---|---|---|---|---|
| 3-30 total time | F=2.936, P<0.089 | n.s. | F=3.426, P<0.069 | n.s. | F= 1.876, P<0.176 | n.s. | F=11.694, P<0.002 | 12>1-3 |
| 3 | F=0.561, P<0.458 | n.s. | F=8.957, P<0.011 | 12<1-3 | F=5.247, P<0.039 | 12>1-3 | F=0.718, P<0.412 | n.s. |
| 6 | F=3.849, P<0.056 | n.s. | F=2.442, P<0.142 | n.s. | F= 0.961, P<0.345 | n.s. | F=4.094, P<0.064 | n.s. |
| 26 | F = 4.131, P<0.0511 | n.s. | F=0.614, P<0.447 | n.s. | F= 0.005, P<0.942 | n.s. | F=1.026, P<0.329 | n.s. |
| 30 | F=1.861, P<0.183 | n.s. | F=1.411, P<0.256 | n.s. | F=6.607, P<0.023 | 12>1-3 | F=20.373, P<0.0006 | 12>1-3 |

## 4. Discussion

The results of our experiment support the hypothesis that the plant litter diversity is an important factor for humus formation in soil and might be an important agent in restoration processes of deteriorated soil systems. Differences were found mainly in humus acid fractions. Sum of fulvic and humic acids content was indeed the highest under the most diverse treatment (V). It was found also that increases of carbon and nitrogen content during growing seasons were significantly higher under mixture treatments compared to single species treatments [18,27]. These changes found at the end of the experiment were not related to litter mass loss. The slowest litter mineralisation was observed for red fescue and the highest for clover in the first year of the experiment. Later data (26 and 30 months) showed no differences between treatments [18].

Algae differentiated experimental treatments more than other biological parameters analysed [18]. It was found that soil respiration under different litter treatments was significantly and positively correlated with algal biomass [27]. In our experiment, the algae were probably the most important factor in the humification processes. Being the main focus of many hydrobiological studies, algae are often neglected in soil studies [18,19,28,29]. It was demonstrated however in recent studies that algae might be involved in fulvic acids formation [18,30]. It seems that mulching with diverse litter (hay) promotes the humus acids accumulation more effectively than mulching with single species.

## 5. Conclusions

In conclusion, our results suggest that the mulching the soil with diverse plant litter (hay) is important for accelerating humus formation and algae development in soil.

## Acknowledgments

This research was supported by a grant from the Polish State Committee for Scientific Research, project P04 F 03820.

## References

[1] K.E. Giller, M.H. Beare, P. Lavelle, A.M.N. Izac, and M.J. Swift, Appl. Soil Ecol., 6(1997)3.
[2] F.S. Chapin III, E.S. Zavaleta, V.T. Eviner, R.L. Naylor, P.M. Vitousek, H.L. Reynolds, D.U. Hooper, S. Lavorel, O.E. Sala, D.C. Coleman, S.E. Hobbie, M.C. Mack, and S. Diaz, Nature, 405(2000)234.
[3] D.U. Hooper, F.S. Chapin III, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Sëtala, A.J. Symstad, J. Vandermeer, and D.A. Wardle, Ecol. Monogr., 75(2005)3.
[4] R. Lal, Prog. Environ. Sci., 1(1999)307.
[5] A. Freibauer, M.D.A. Rounsevell, P. Smith, and J. Verhagen, Geoderma, 122(2004)1.
[6] R.K. Shrestha, and R. Lal, Environ. Int., 32(2006)781.
[7] T. Cong, J.B. Ristaino, and S. Hu, Soil Biol. Biochem., 38(2006)247.
[8] K.O. Adekalu, I.A. Olorunfemi, and J.A. Osunbitan, Bioresour. Technol., 98(2007)912.
[9] S. Fang, J. Liu, D. Liu, and B. Xie, Soil Sci. Plant Nutr., 56(2010)483.
[10] A. Kajak, Agric. Ecos. Environ., 64(1997)55.
[11] S.C. Dekker, S. Scheu, D. Schröter, H. Setälä, M. Szanser, and T.P. Traas, Dynamic Food Webs - multispecies assemblages, ecosystem development and environmental change, Elsevier, Amsterdam, The Netherlands, 2005.
[12] Z. Luo, E. Wang, and O.J. Sun, Geoderma, 155(2010)211.
[13] J.F. Ponge, Soil Biol. Biochem., 35(2003)935.
[14] L. Ryszkowski, J. Karg, and J. Pudełko (Eds.), Ekologiczne procesy w monokulturowych uprawach zbóż (Ecological processes in continuous cropping of rye), Poznań, Poland, 1990 (in Polish).
[15] A. Kajak, and L. Wasilewska, Ekol. Pol., 45(1997)839.
[16] D.A. Wardle, K.I. Bonner, G.M. Barker, G.W. Yeates, K.S. Nicholson, R.D. Bardgett, R.N. Watson, and A. Ghani, Ecol. Monogr., 69(1999) 535.
[17] E.M. Spehn, A. Hector, J. Joshi, M. Scherer-Lorenzen, B. Schmid, E. Bazeley-White, C. Beierkuhnlein, M.C. Caldeira, M. Diemer, P.G. Dimitrakopoulos, J.A. Finn, H. Freitas, P.S. Giller, J. Good, R. Harris, P. Högberg, K. Huss-Danell, A. Jumpponen, J. Koricheva, P.W. Leadley, M. Loreau, A. Minns, C.P.H. Mulder, G. O'Donovan, S.J. Otway, C. Palmborg, J.S. Pereira, A.B. Pfisterer, A. Prinz, D.J. Read, E.-D. Schulze, A.-S.D. Siamantziouras, A.C. Terry, A.Y. Troumbis, F.I. Woodward, S. Yachi, and J.H. Lawton, Ecol. Mon., 75(2005)37.
[18] M. Szanser, K. Ilieva-Makulec, A. Kajak, E. Górska, A. Kusińska, M. Kisiel, I. Olejniczak, S. Russel, D. Sieminiak, and D. Wojewoda, Soil Biol. Biochem., 43(2011)9.
[19] O. Rahmonov, and J. Piątek, Ecológia (Bratislava), 26(2007)52.
[20] M. Szanser, Pol. J. Ecol., 48(2000)271.
[21] S.C. Pearce, The Agricultural Field Experiment: a Statistical Examination of Theory and Practice, New York, John Wiley & Sons, USA, 1983.
[22] A. Kajak, A. Kusińska, S. Stanuszek, O. Stefaniak, M. Szanser, A. Wasylik, and L. Wasilewska, Pol. J. Ecol., 48(2000)339.
[23] M.M. Kononova, Soil Organic Matter, Pergamon Press, Oxford, UK, 1966.
[24] R.D. Wood, Hydrobiological Methods, University Park Press, Baltimore, London, Tokyo, 1975.
[25] D. Sieminiak, Ekol. Polska, 44(1996)225.

[26] StatSoft Inc., STATISTICA (data analysis software system), version 8.0. http://www.statsoft.com/, 2007.
[27] M. Szanser, E. Górska, M. Kisiel, A. Kusińska, S. Russel, D. Sieminiak, and D. Wojewoda, Plant Breeding and Seed Science, 61(2010)47.
[28] J. Jahnke, and U.B. Priefer, Soil Biol. Biochem., 34(2002)1157.
[29] S. Zancan, R. Trevisan, and M.G. Paoletti, Agric. Ecos. Environ., 112(2006)1.
[30] J. Mao, R.M. Cory, D.M. Mc Knight, and K. Schmidt-Rohr, Org. Geochem., 38(2007)1277.